CLAIMS

1. A qubit, comprising:

   a multi-terminal junction having at least two terminals; and

   a superconducting loop coupled between two of the at least two terminals;

   wherein the superconducting loop provides a phase shift.

2. The qubit of Claim 1, wherein the multi-terminal junction includes at least one constriction junction.

3. The qubit of Claim 1, wherein the multi-terminal junction includes at least one tunnel junction.

4. The qubit of Claim 3, wherein the tunnel junction is formed by an insulating layer separating two of the at least two terminals.

5. The qubit of Claim 4, wherein the two of the at least two terminals are an s-wave superconducting material.

6. The qubit of Claim 1, wherein the multi-terminal junction includes at least one two-dimensional electron gas structure.

7. The qubit of Claim 6, wherein the at least one two-dimensional electron gas structure is an InAs layer deposited on an AlSb substrate.

8. The qubit of Claim 1, wherein the superconducting loop includes a first portion of a s-wave superconducting material and a second portion of a s-wave superconducting material and wherein a portion of the phase shift is produced by a d-wave superconducting material coupled to the first portion and the second portion through normal metal interfaces, the portion of the phase shift being determined by the angle between the normal metal

interface and crystallographic directions in the d-wave superconducting material.

9. The qubit of Claim 1, wherein the superconducting loop includes a first portion of a s-wave superconducting material and a second portion of a s-wave superconducting material and wherein a portion of the phase shift is produced by a first d-wave superconducting material coupled through a normal metal to the first portion and a second d-wave superconducting material coupled through a second normal metal to the second portion, the portion of the phase shift being determined by the difference in crystallographic directions in a grain boundary interface between the first d-wave superconducting material and the second d-wave superconducting material.

10. The qubit of Claim 9, wherein the first d-wave superconducting material and the second d-wave superconducting material are formed on insulating crystals.

11. The qubit of Claim 9, wherein the s-wave superconducting material is chosen from a group consisting of Aluminum, Niobium, Lead, Mercury, and Tin.

12. The qubit of Claim 9, wherein the d-wave superconducting material is $YBa_2Cu_3O_{7-x}$.

13. The qubit of Claim 10, wherein the insulating crystals can be chosen from the group consisting of Strontium Titanate, Sapphire, Cerium Oxide, and Magnesium Oxide.

14. The qubit of Claim 1, wherein a portion of the phase shift is produced by a ferromagnetic junction.

15. The qubit of Claim 14, wherein the superconducting loop includes a first portion and a second portion, the first portion and the second portion being coupled by the ferromagnetic junction.

16. The qubit of Claim 15, wherein the first portion and the second portion are each s-wave superconducting material.

17. The qubit of Claim 16, wherein the s-wave superconducting material is chosen from the group consisting of Aluminum, Niobium, Lead, Mercury, and Tin.

18. The qubit of Claim 16, wherein the ferromagnetic junction is formed by copper or Nickel sandwiched between the first portion and the second portion.

19. The qubit of Claim 16, wherein the ferromagnetic junction is provided by implanting a ferromagnetic material into the s-wave superconducting material between the first portion and the second portion.

20. The qubit of Claim 1, wherein the superconducting loop is formed from a d-wave superconducting material and wherein a portion of the phase shift is formed by grain boundaries in the d-wave superconducting material of the superconducting loop.

21. The qubit of Claim 1, wherein the at least two terminals includes four terminals and the multi-terminal junction includes a four-terminal constriction junction which couples the four terminals.

22. The qubit of Claim 1, wherein the at least two terminals includes four terminals and the multi-terminal junction includes a constriction junction coupling two of the four terminals, a first tunneling junction coupling a third of the four terminals to one of the two terminals coupled by the

constriction junction, and a second tunneling junction coupling a fourth of the four terminals to one of the two terminals coupled by the constriction junction.

23. The qubit of Claim 22 wherein each of the first tunneling junction and the second tunneling junction are arranged to be substantially parallel with one of the two terminals coupled together by the constriction junction.

24. The qubit of Claim 1, wherein the at least two terminals includes four terminals and the multi-terminal junction includes a tunneling junction coupling a first of the four terminals with a second of the four terminals, a first constriction junction coupling the second of the four terminals with a third of the four terminals, and a second constriction junction coupling the third of the four terminals with a fourth of the four terminals.

25. The qubit of Claim 24 wherein the tunneling junction is substantially parallel with the second of the four terminals.

26. The qubit of Claim 1, wherein the at least two terminals includes four terminals coupled by a two-dimensional electron gas structure.

27. The qubit of Claim 1, wherein the at least two terminals includes four terminals, three of which are coupled by a two-dimensional electron gas structure and the fourth coupled to one of the three with a constriction junction.

28. The qubit of Claim 1, wherein the at least two terminals includes four terminals, three of which are coupled by a two-dimensional electron gas structure and the fourth coupled to one of the three with a tunneling junction.

29. The qubit of Claim 1, wherein the multi-terminal junction includes a constriction junction coupling each of the at least two terminals.

30. The qubit of Claim 1, wherein the multi-terminal junction includes a constriction junction coupling a first terminal with a second terminal and at least one tunneling junction coupling at least one other terminal to the first terminal and the second terminal.

31. The qubit of Claim 1, wherein the multi-terminal junction includes an electron gas structure coupling each of the at least two terminals.

32. The qubit of Claim 1, wherein the multi-terminal junction is a three-terminal junction.

33. The qubit of Claim 1, wherein the multi-terminal junction is a four-terminal junction.

34. The qubit of Claim 1, wherein the multi-terminal junction is a five-terminal junction.

35. The qubit of Claim 1, wherein the multi-terminal junction is a six-terminal junction.

36. The qubit of Claim 1, wherein the multi-terminal junction includes more than six terminals.

37. The qubit of Claim 1, wherein the multi-terminal junction is capable of symmetrically transporting current.

38. The qubit of Claim 1, wherein the multi-terminal junction is capable of asymmetrically transporting current.

39. A qubit, comprising:

means for coupling a plurality of terminals;

means for forming a superconducting loop between two of the plurality of terminals;

means for providing a phase shift in the superconducting loop.

40. The qubit of Claim 39, wherein the means for coupling a plurality of terminals includes a two-dimensional electron gas junction.

41. The qubit of Claim 39, wherein the means for coupling a plurality of terminals includes a tunnel junction.

42. The qubit of Claim 39, wherein the means for coupling a plurality of terminals includes a constriction junction.

43. The qubit of Claim 39, wherein the means for providing a phase shift includes providing a d-wave superconductor material coupled into the superconducting loop.

44. The qubit of Claim 39, wherein the means for providing a phase shift includes a grain boundary between two lattice-mismatched d-wave superconducting materials.

45. The qubit of Claim 39, wherein the means for providing a phase shift includes a ferromagnetic junction.

46. A qubit array, comprising:

a plurality of qubits, at least one of the plurality of qubits comprising a multi-terminal junction with two terminals coupled to form a

superconducting loop, the superconducting loop providing a phase shift.

47. The array of Claim 46, wherein the multi-terminal junction includes at least one constriction junction.

48. The array of Claim 46, wherein the multi-terminal junction includes at least one tunnel junction.

49. The array of Claim 48, wherein the tunnel junction is formed by an insulating layer separating two of the at least two terminals.

50. The array of Claim 49, wherein the two of the at least four terminals are an s-wave superconducting material.

51. The array of Claim 46, wherein the multi-terminal junction includes at least one two-dimensional electron gas structure.

52. The array of Claim 51, wherein the at least one two-dimensional electron gas structure is an InAs layer deposited on an AlSb substrate.

53. The array of Claim 46, wherein the superconducting loop includes a first portion of a s-wave superconducting material and a second portion of a s-wave superconducting material and wherein a portion of the phase shift is produced by a d-wave superconducting material coupled to the first portion and the second portion through normal metal interfaces, the portion of the phase shift being determined by the angle between the normal metal interface and crystallographic directions in the d-wave superconducting material.

54. The array of Claim 46, wherein the superconducting loop includes a first portion of a s-wave superconducting material and a second portion of a s-wave superconducting material and wherein a portion of the phase shift is produced by a first d-wave superconducting material coupled through a normal metal to the first portion and a second d-wave superconducting material coupled through a second normal metal to the second portion, the portion of the phase shift being determined by the difference in crystallographic directions in a grain boundary interface between the first d-wave superconducting material and the second d-wave superconducting material.

55. The array of Claim 54, wherein the first d-wave superconducting material and the second d-wave superconducting material are formed on insulating crystals.

56. The array of Claim 54, wherein the s-wave superconducting material is chosen from a group consisting of Aluminum, Niobium, Lead, Mercury, and Tin.

57. The array of Claim 54, wherein the d-wave superconducting material is $YBa_2Cu_3O_{7-x}$.

58. The array of Claim 55, wherein the insulating crystals can be chosen from the group consisting of Strontium Titanate, Sapphire, Cerium Oxide, and Magnesium Oxide.

59. The array of Claim 46, wherein a portion of the phase shift is produced by a ferromagnetic junction.

60. The array of Claim 59, wherein the superconducting loop includes a first portion and a second portion, the first portion and the second portion being coupled by the ferromagnetic junction.

61. The array of Claim 60, wherein the first portion and the second portion are each s-wave superconducting material.

62. The array of Claim 61, wherein the s-wave superconducting material is chosen from the group consisting of Aluminum, Niobium, Lead, Mercury, and Tin.

63. The array of Claim 61, wherein the ferromagnetic junction is formed by copper or Nickel sandwiched between the first portion and the second portion.

64. The array of Claim 61, wherein the ferromagnetic junction is provided by implanting a ferromagnetic material into the s-wave superconducting material between the first portion and the second portion.

65. The array of Claim 46, wherein the superconducting loop is formed from a d-wave superconducting material and wherein a portion of the phase shift is formed by grain boundaries in the d-wave superconducting material of the superconducting loop.

66. The array of Claim 46, wherein the multi-terminal junction couples at least four terminals, two of the at least four terminals being coupled to the superconducting loop, at least one of the remaining two terminals being coupled to a multi-terminal junction of another of the plurality of qubits to form a series connection.

67. The array of Claim 46, wherein the multi-terminal junction couples at least six terminals and wherein the plurality of qubits includes a first superconducting loop and a second superconducting loop, the first superconducting loop being coupled to a first pair of the six terminals and

the second superconducting loop being coupled to a second pair of the six terminals.

68. The array of Claim 67, wherein a third pair of the six terminals is coupled to a current source.

69. The array of Claim 67, wherein the second superconducting loop is further coupled to a first pair of terminals from a second one multi-terminal junction.

70. The array of Claim 67, wherein at least one of the six terminals is coupled to a coupling junction, the coupling junction being coupled to a junction which is coupled to at least one superconducting loop.

71. The array of Claim 46, wherein at least two of the plurality of qubits share a shared multi-terminal junction.

72. The array of Claim 71, wherein the shared multi-terminal junction is a six-terminal junction.

73. The array of Claim 46, wherein at least two of the plurality of qubits include a superconducting loop and at least two of the superconducting loops are switchably coupled with an entanglement junction.

74. The array of Claim 73, wherein the entanglement junction includes a plate which can capacitively couple a voltage to a coupling junction joining the at least two superconducting loops.

75 The entanglement junction of claim 74, wherein the plate is a structure that allows capacitive coupling of a voltage to the coupling junction.

76. The array of Claim 74, wherein the voltage determines whether the coupling junction is open or closed.

77. The array of Claim 76, wherein the coupling junction is a two dimensional electron gas.

78. The array of Claim 77, wherein the entanglement junction further controls the coupling of at least one of the at least two superconducting loops with the multi-terminal junction.

79. The array of Claim 77, wherein the coupling junction includes a tunnel junction.

80. An array of qubits, comprising

a plurality of qubits, each qubit of the plurality of qubits including a superconducting loop coupled to a multi-terminal junction, the superconducting loop providing a phase shift; and

an entanglement junction coupling superconducting loops of two qubits of the plurality of qubits.

81. The qubit of Claim 80, wherein the multi-terminal junction of at least one of the plurality of qubits includes at least one constriction junction.

82. The qubit of Claim 80, wherein the multi-terminal junction of at least one of the plurality of qubits includes at least one tunnel junction.

83. The qubit of Claim 80, wherein the multi-terminal junction of at least one of the plurality of qubits includes at least one two-dimensional electron gas structure.

84. The qubit of Claim 80, wherein the superconducting loop of at least one of the plurality of qubits includes a first portion of a s-wave superconducting material and a second portion of a s-wave superconducting material and wherein a portion of a phase shift is produced by a d-wave superconducting material coupled to the first portion and the second portion through normal metal interfaces, the portion of the phase shift being determined by the angle between the normal metal interface and crystallographic directions in the d-wave superconducting material.

85. The qubit of Claim 80, wherein the superconducting loop of at least one of the plurality of qubits includes a first portion of a s-wave superconducting material and a second portion of a s-wave superconducting material and wherein a portion of a phase shift is produced by a first d-wave superconducting material coupled through a normal metal to the first portion and a second d-wave superconducting material coupled through a second normal metal to the second portion, the portion of the phase shift being determined by the difference in crystallographic directions in a grain boundary interface between the first d-wave superconducting material and the second d-wave superconducting material.

86. The qubit of Claim 80, wherein the superconducting loop of at least one of the plurality of qubits provides a phase shift, a portion of the phase shift being produced by a ferromagnetic junction.

87. The qubit of Claim 80, wherein the superconducting loop of at least one of the plurality of qubits is formed from a d-wave superconducting material and wherein a portion of a phase shift is formed by grain boundaries in the d-wave superconducting material of the superconducting loop.

88. The array of Claim 80, wherein the entanglement junction comprises:

a multi-terminal junction coupled between the the superconducting loops of two of the plurality of qubits; and

a plate proximate the multi-terminal junction to capacitively couple a potential into the coupling junction.

89 The entanglement junction of claim 88, wherein the plate is a structure that allows a voltage to be capacitively coupled to the coupling junction.

90. The array of Claim 88, wherein the multi-terminal junction of the entanglement junction includes a two-dimensional electron gas.

91. The array of Claim 88, wherein the multi-terminal junction of the entanglement junction is separated from, and not part of, the portion of the superconducting loops that the multi-terminal junction couples where the flux is maintained.

92. The array of Claim 91, wherein quantum states on the superconducting loops of the two superconducting loops of the two qubits are entangled or not entangled in response to voltages applied to the plate of the entanglement junction.

93. The array of Claim 92, wherein the quantum states are entangled if no voltage is applied to the plate and not entangled if a voltage is applied to the plate.